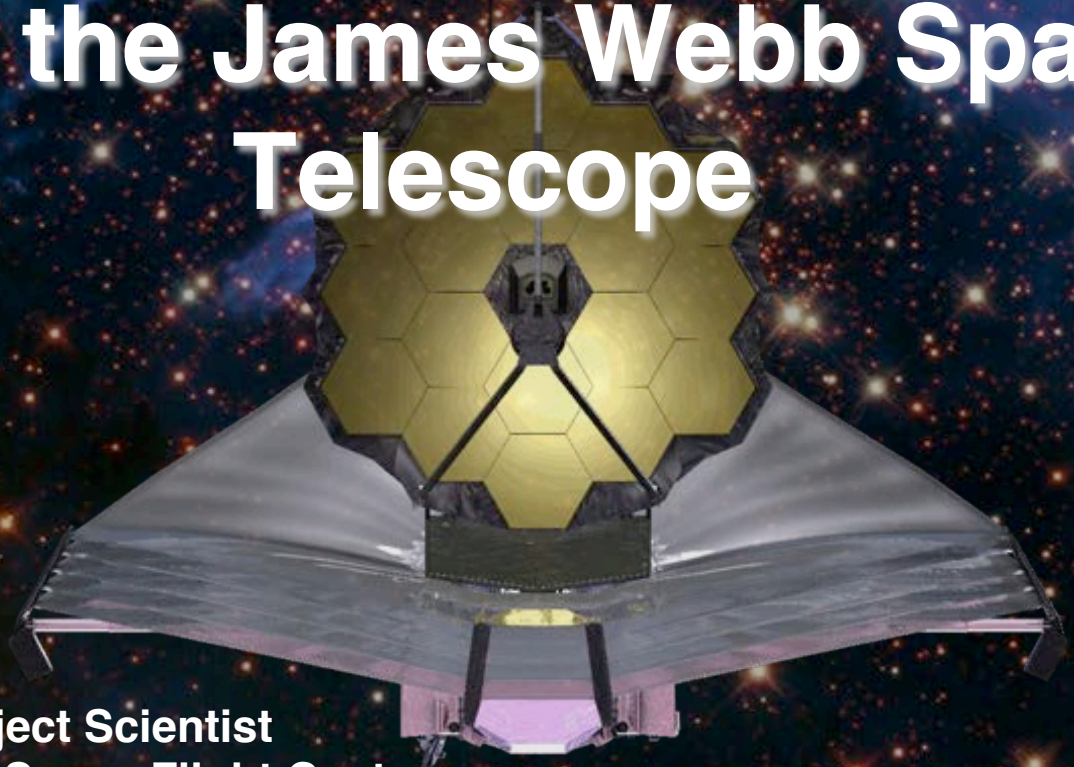
Observing the History of the Universe from Beginning to End, with the James Webb Space Telescope



John Mather
JWST Senior Project Scientist
NASA's Goddard Space Flight Center

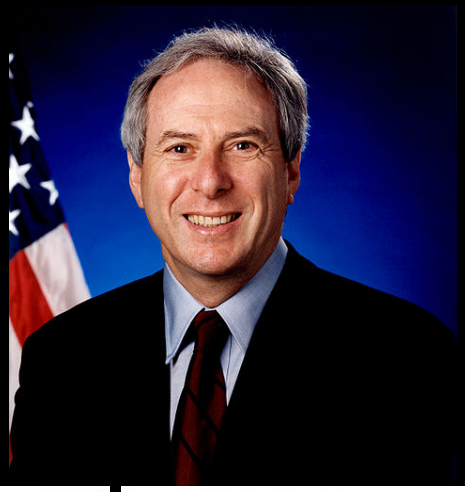
on behalf of 7 billion current Earthlings, ~10,000 future observers, > 2000 engineers and technicians, ~ 100 scientists worldwide, 3 space agencies

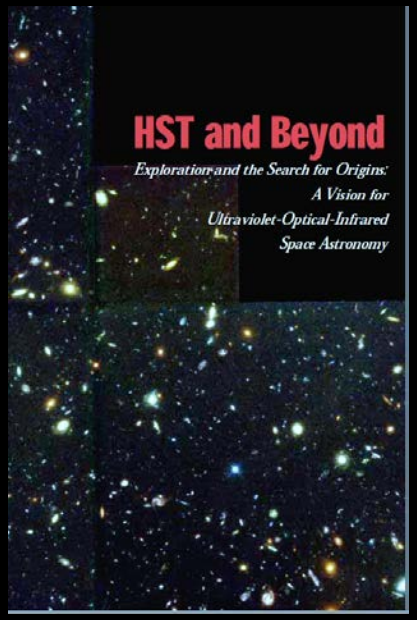
Ideas + technology = excitement!

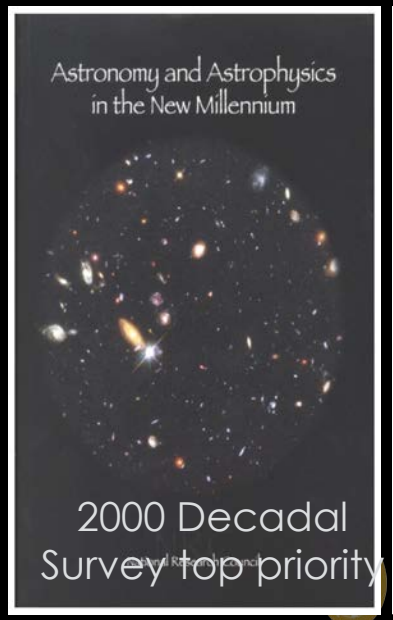
"I see Alan Dressler here. All he wants is a four meter optic that goes from a half micron to 20 microns. And I said to him, "Why do you ask for such a modest thing? Why not go after six or seven meters?"

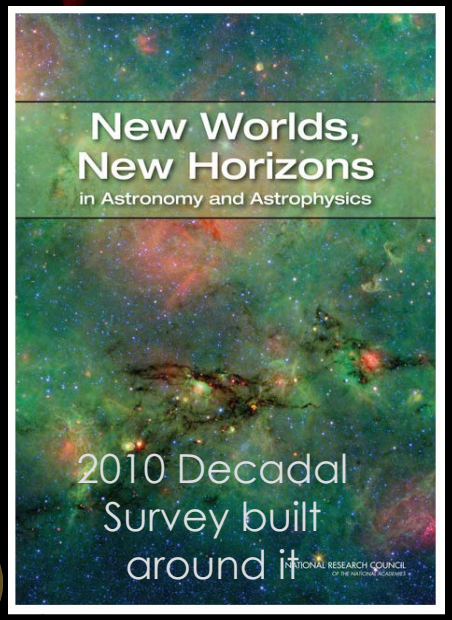
(standing ovation after speech)

Dan Goldin, 1996 American Astronomical Society meeting



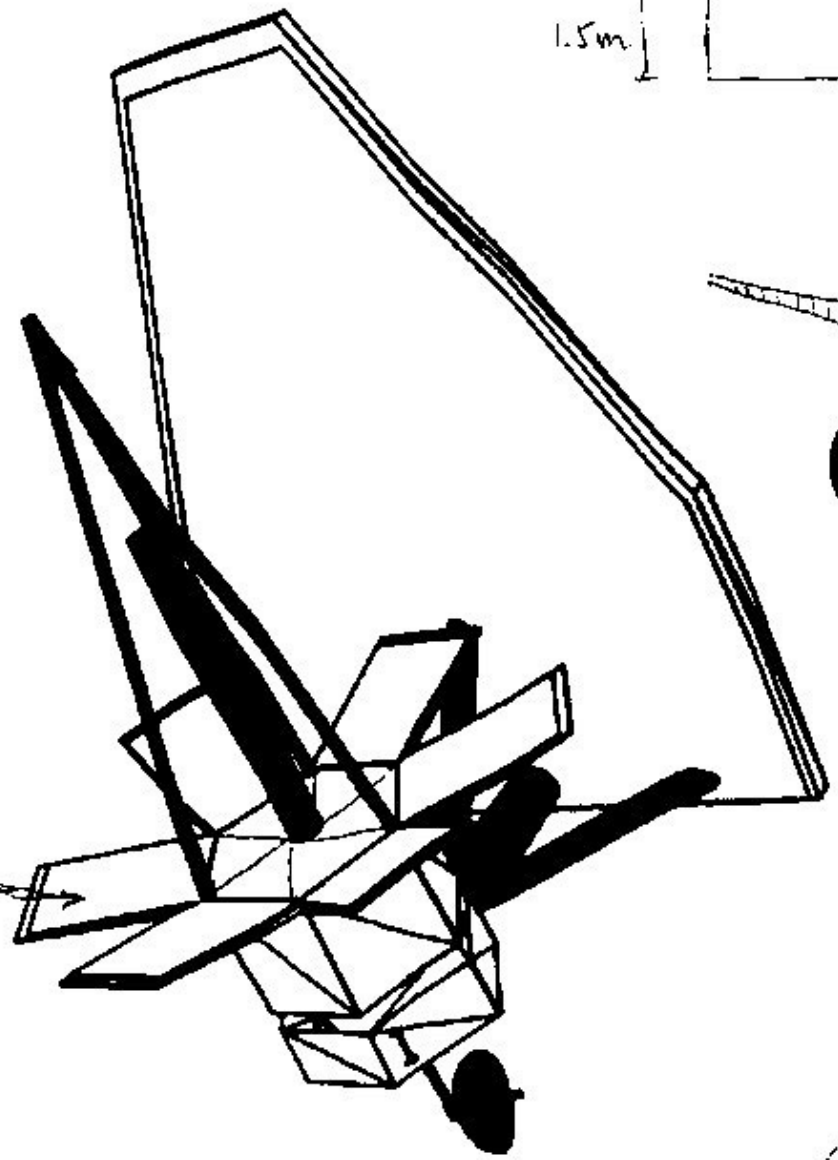


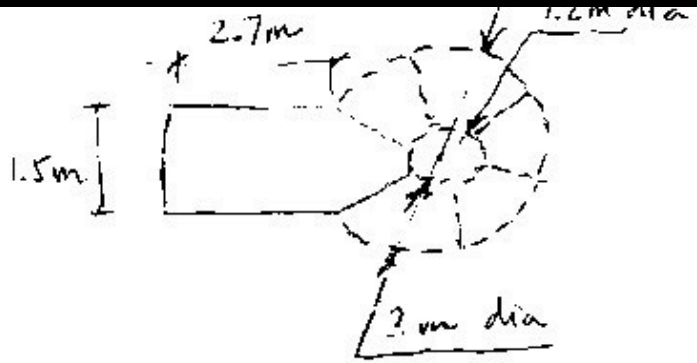


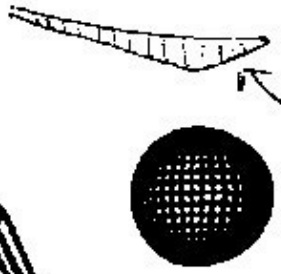


TELESCOPE

PRIMARY MIRROR

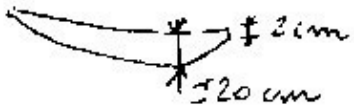




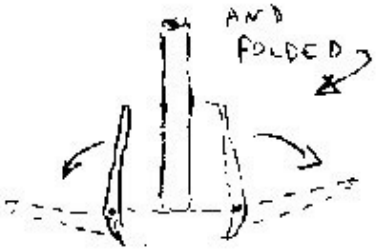


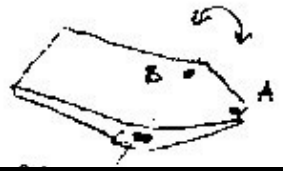
CROSS SECTION OF A PETAL (OPEN BACK)

THICKNESS OF PETAL DETERMINED BY NATURAL FREQUENCY WHEN HELD AT 3 POINTS (KINEMATICALLY) PROBABLY ≃ 2 CM AT EDGE AND ≃ 20 CM AT THICKEST SECTION :



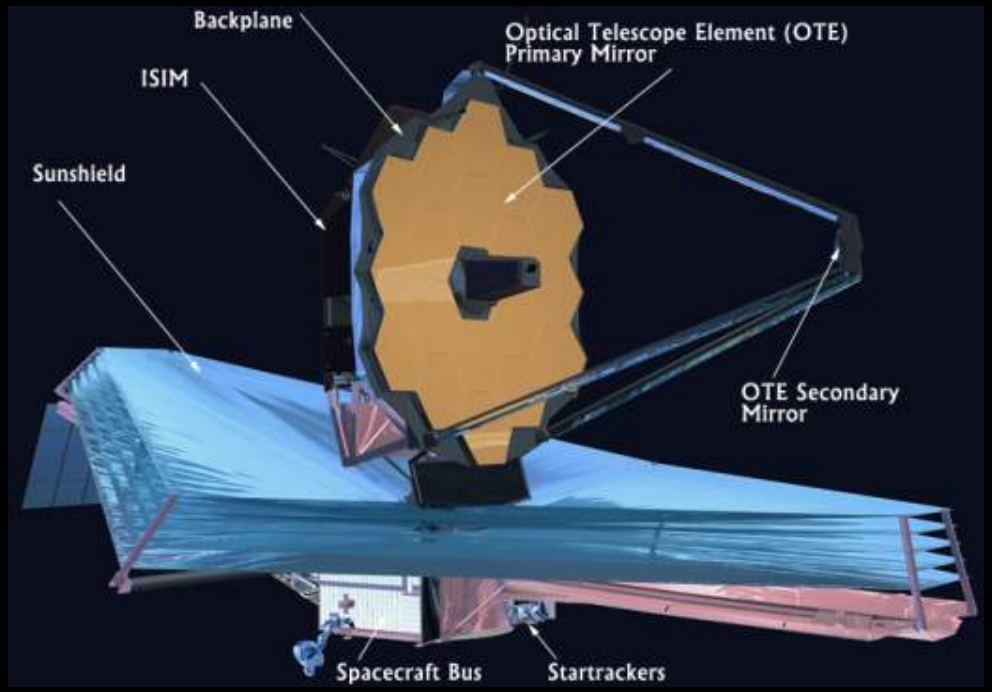
PETAL SHOWN DEPLOYED AND FOLDED





JWST Circa 2000

James Webb Space Telescope (JWST)



Organization

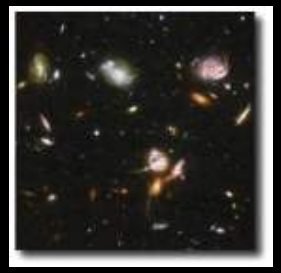
- Mission Lead: NASA/Goddard Space Flight Center
- International collaboration with ESA & CSA
- Observatory Contractor: Northrop Grumman Aerospace Systems
- Instruments:
  - Near Infrared Camera (NIRCam) – Univ. of Arizona
  - Near Infrared Spectrograph (NIRSpec) – ESA
  - Mid-Infrared Instrument (MIRI) – JPL/ESA/EC
  - Fine Guidance Sensor (FGS) and Near IR Imaging Slitless Spectrometer (NIRISS) – CSA
- Operations: Space Telescope Science Institute

Description

- Deployable infrared telescope with 6.5 meter diameter segmented adjustable primary mirror
- Cryogenic temperature telescope and instruments for infrared performance
- Launch on an ESA-supplied Ariane 5 rocket to Sun-Earth L2
- 5-year science mission (10-year goal)

www.JWST.nasa.gov

JWST Science Themes



End of the dark ages: First light and reionization

The assembly of galaxies

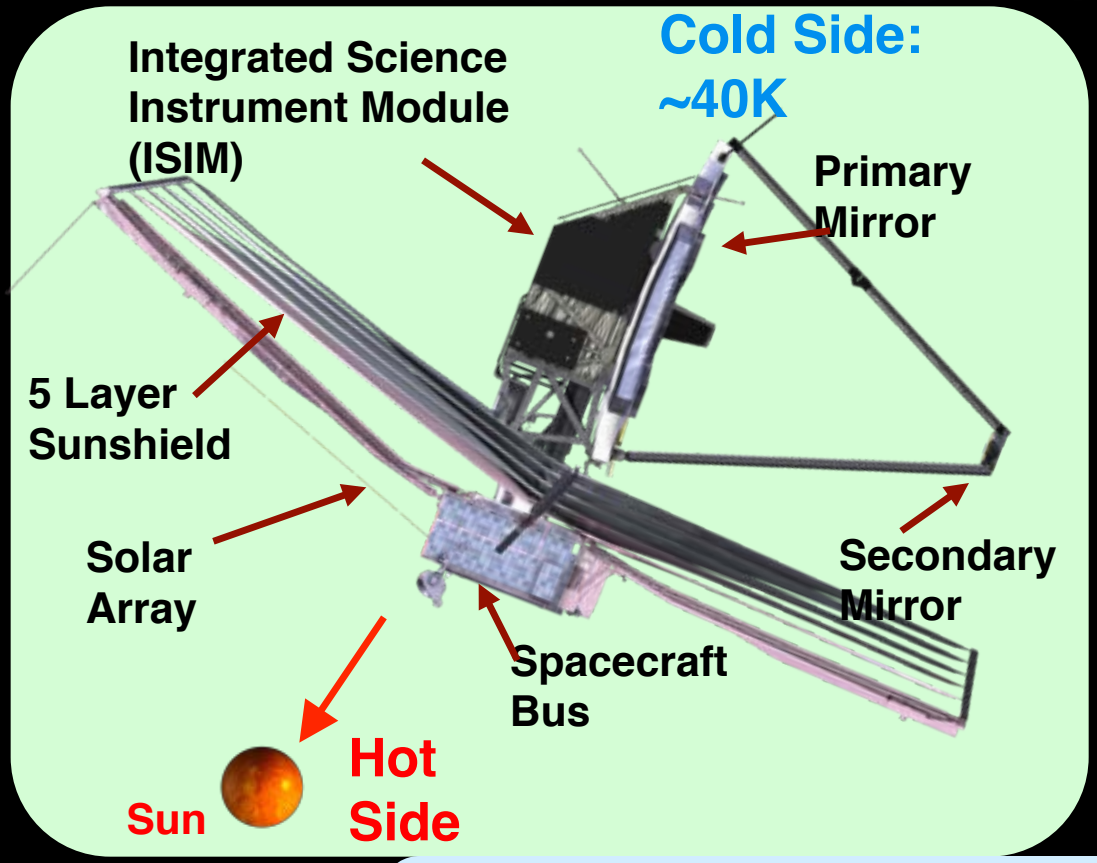
Birth of stars and proto-planetary systems

Planetary systems and the origin of life

JWST Vital Stats

- General Observatory: 5 years required; 10 years goal
- Diameter of primary mirror: 21.3 feet (6.5 meters)
- Number of primary mirror segments: 18
- Sunshield: 5 layer, 69.5 feet by 46.5 feet (21.2 meters by 14.2 meters
- Orbit: 930,000 miles (1.5 million kilometers) from Earth
- Operating temperature: Below 50 Kelvin (–370° Fahrenheit)
- Four Science Instruments covering 0.6–28.5 microns (diffraction limited at 2 microns)
  - Filtered Imaging
  - Spectroscopy – Slit, Integral Field, Grism/Prism
  - Coronagraphy – Traditional Lyot + Four Quadrant Phase Masks
  - Aperture Mask Interferometry – Non-Redundant Mask (NRM)

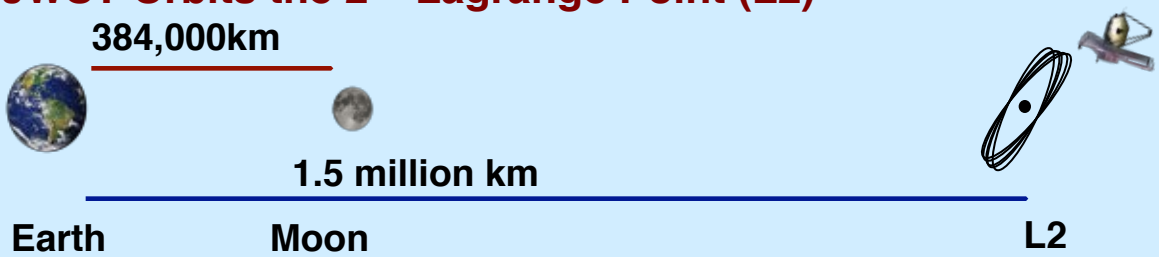
HOW JWST WORKS



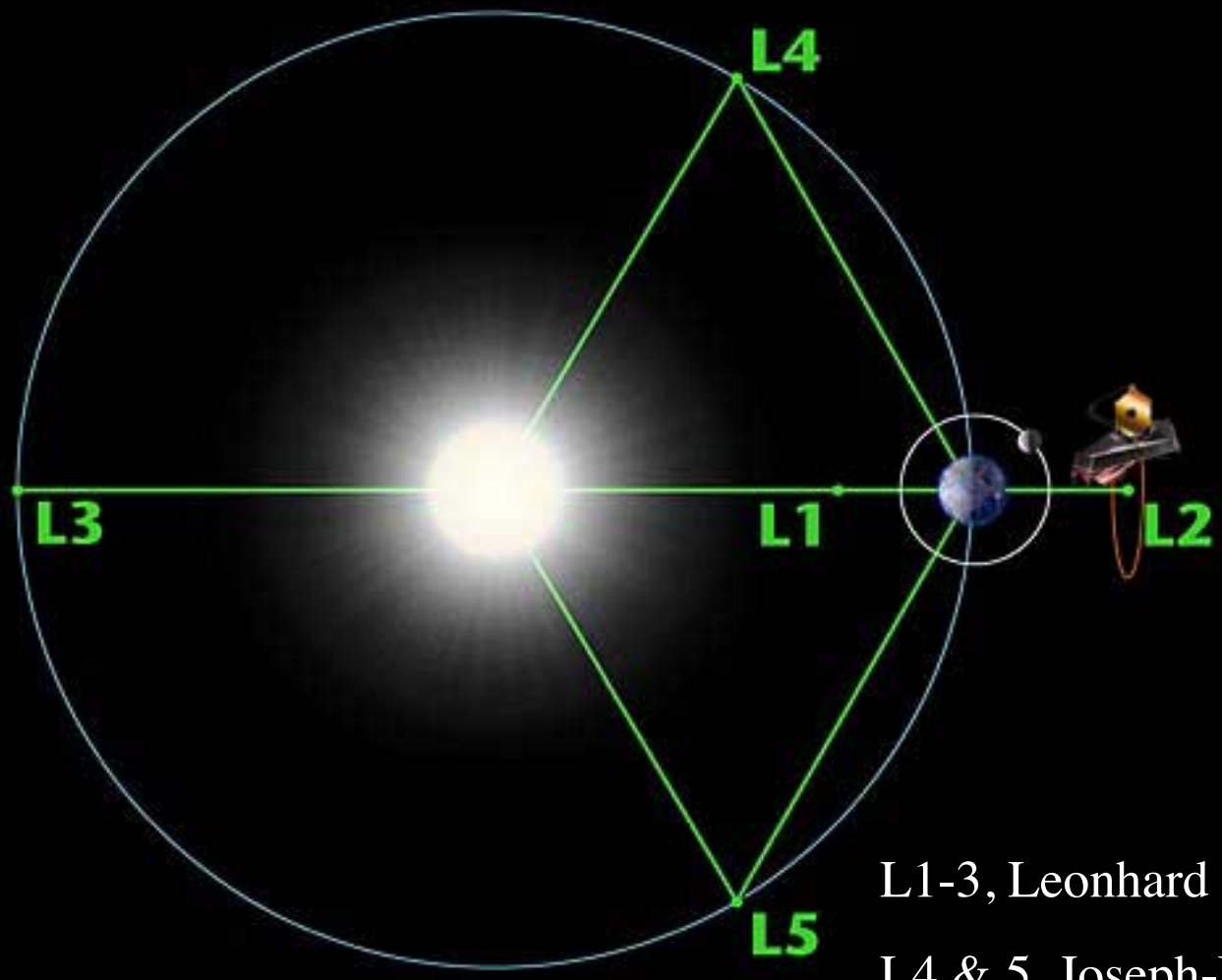
JWST is folded and stowed for launch

Observatory is deployed after launch

JWST Orbits the 2nd Lagrange Point (L2)



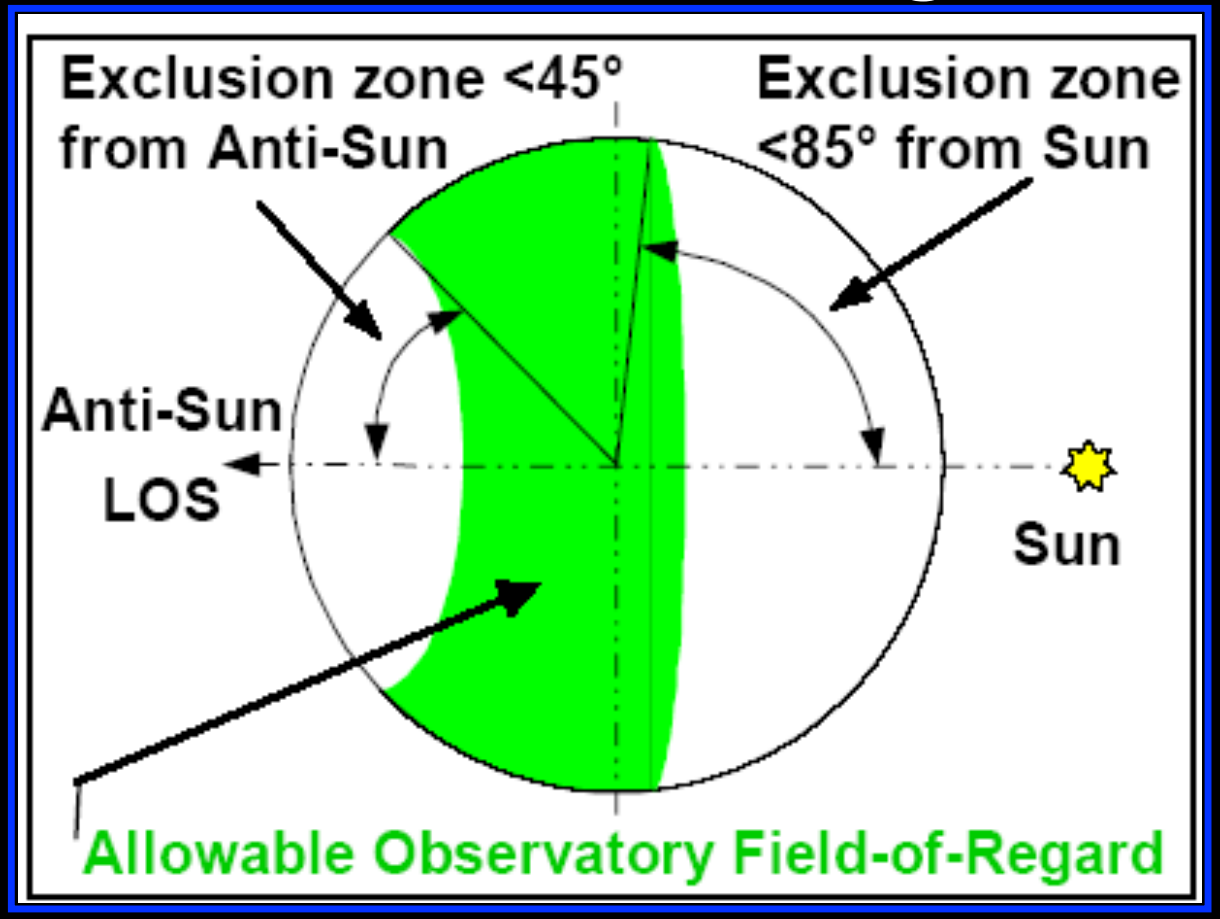
JWST Orbits the Sun-Earth Lagrange Point L2



L1-3, Leonhard Euler, 1750.

L4 & 5, Joseph-Louis Lagrange, 1772

JWST Field of Regard



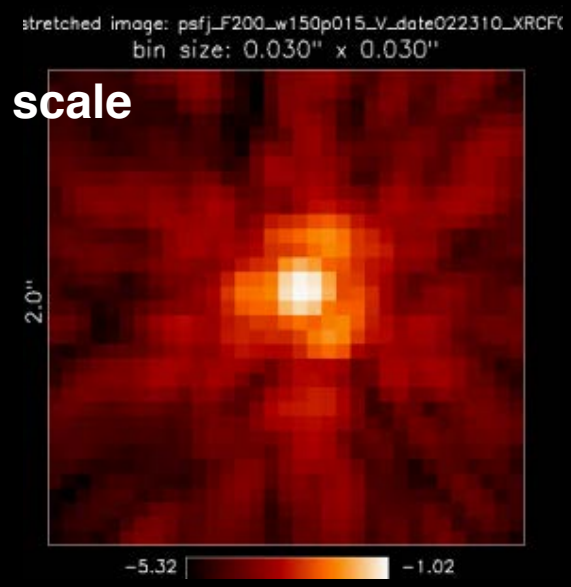
- JWST's optics must always be fully shaded
  - Solar-system observations will be made near quadrature
    - Similar to Spitzer and Herschel observatories

Testbed Telescope

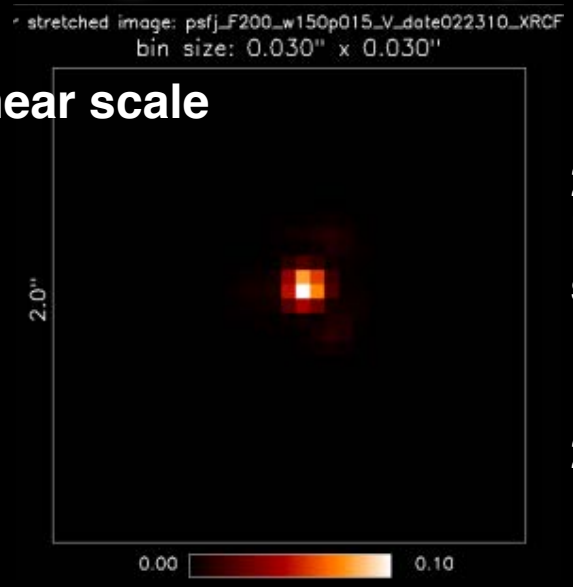
- 1/6 scale model with all the same adjustments
- Proves that all the adjustment procedures work as expected

Predicted Image Quality

Log scale

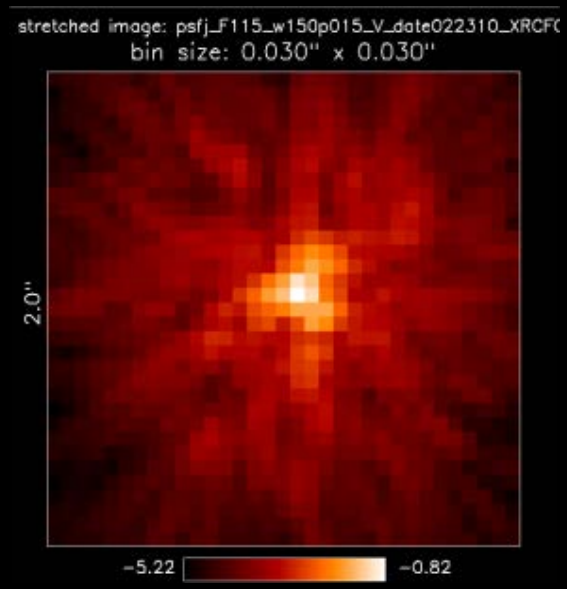


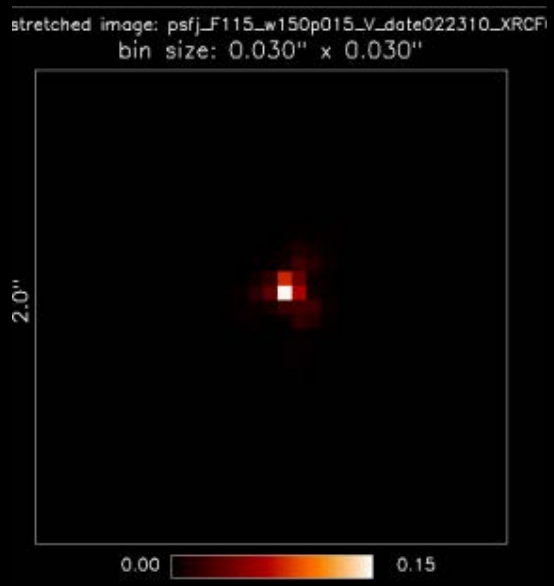
Linear scale



2 µm (diffraction limited, Nyquist sampled by NIRCam)

2.0” x 2.0” box



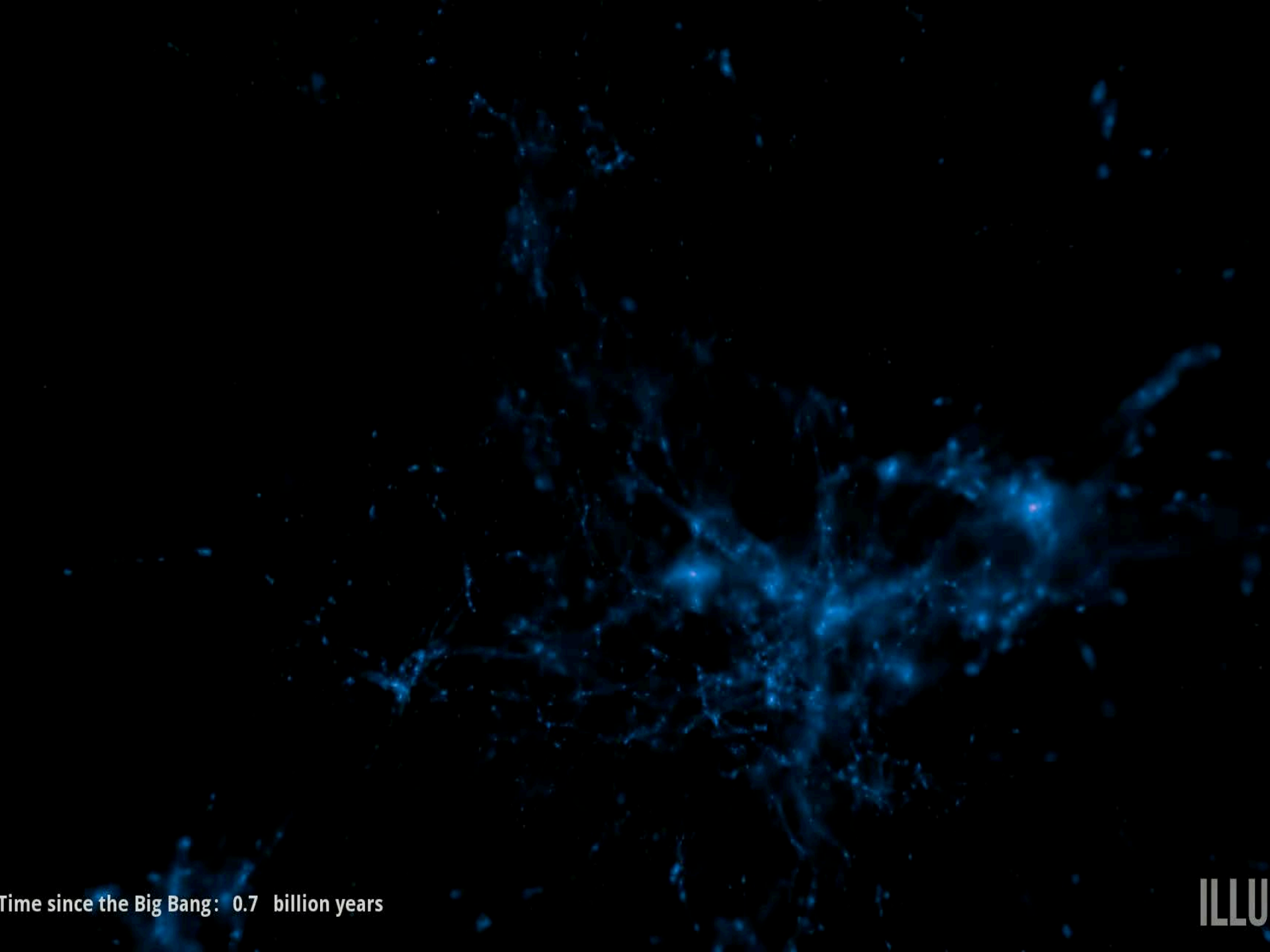


1 µm (sharp core 0.03 arcsec)

2.0” x 2.0” box

JWST Instrumentation

Instrument	Science Requirement	Capability
NIRCam Univ. Az/LMATC	Wide field, deep imaging ›0.6 μm - 2.3 μm (SW) ›2.4 μm - 5.0 μm (LW)	2.2' x 4.4' SW at same time as 2.2' x 4.4' LW with dichroic Coronagraph
NIRSpec ESA/Astrium	Multi-object spectroscopy ›0.6 μm - 5.0 μm	9.7 Sq arcmin Ω + IFU + slits 100 selectable targets: MSA R=100, 1000, 3000
MIRI ESA/Consortium /UKATC/JPL	Mid-infrared imaging › 5 μm - 27 μm Mid-infrared spectroscopy › 4.9 μm - 28.8 μm	1.9' x1.4' with coronagraph 3.7"x 3.7" – 7.1"x 7.7" IFU R=3000 - 2250
FGS/NIRISS CSA	Fine Guidance Sensor 0.8 μm - 5.0 μm Near IR Imaging Slitless Spectrometer	Two 2.3' x 2.3' 2.2' x 2.2' R= 700 with coronagraph


Time since the Big Bang: 0.7 billion years
ILLU

Primary

- Planet blocks light from star
- Visible/NIR light (Hubble/JWST/Kepler 4000 planets)
- Radius of planet/star
- Absorption spectroscopy of planet's atmosphere
- JWST: Look for moons, constituents of atmospheres for gas giants to Super-Earths

Secondary

- Star blocks light from planet
- Mid-Infrared light (Spitzer/JWST)
- Direct detection of photons from planet
- Atmospheric composition, structure (T-P profile)
- Global energy budget, clouds
- JWST: Atmospheric characterization, map planets

Mather 2015

JWST Solar System Observing

- JWST will fully support Solar System observations
  - Costs approved through NASA Planetary Sciences Division (2008)
  - Planets, satellites & rings (Mars outward)
  - Asteroids, ice-teroids (KBOs) and comets
- Non-sidereal tracking implemented
  - Rates up to 30 mas/sec (108 "/hr) for Cycle 1 (maybe higher for Cycle 2)
    - Covers everything except fastest NEOs, comets
  - Ephemeris represented as 5th O polynomial, 0.4 mas accuracy
  - Jitter ~7 mas over 1000 sec

Observer Support – Improving on HST

- Planning tools (APT) being updated
  - Target specification via name/ID
  - Observation visualization (MSA planning, mosaics, moving targets)
  - Support for parallel observing modes being developed
- Exposure time calculator integrated with APT
  - Tailor exposure time to science-driven SNR goal
  - Background and stray light model included in ETC
  - Provide best-knowledge performance to entire community
- Pipeline data products
  - Calibrated, science-ready data products for all observing modes

GTO & GO Time

- GTO (guaranteed time observer) target lists final prior to GO-1 call for proposals (~late 2017)
- Joint joint US-Europe-Canada TAC, selection on scientific merit
- GO-1 (general observer) proposals due early 2018 (process & tools similar to HST)
- Science Operations start ~ April, 2019
- First 5 years: 80% GO, 10% DD (Director's Discretionary), 10% GTO
- Second 5 years 90% GO, 10% DD
- Allocation by major science field will reflect fraction of the total available time requested – so ask!
- Analysis funding from NASA for successful US-based proposers

From Beginnings to Planets

The End

And the beginning!

Brief Project History

- 1989, NGST conference at STScI
- 1995, Study initiated by Ed Weiler at GSFC
- 1995, HST and Beyond report (“Dressler report”)
- 1996, government + 2 industry teams report concepts
- Years of technical studies, science working groups
- 2001, GSFC prepares prime procurement
- 2002, HQ selects flight SWG
- 2002, Sept. 10, GSFC selects TRW for $825M BCD
- Name chosen by HQ: James Webb Space Telescope
- TRW becomes Northrop Grumman Space Technologies
- NGST <==> JWST